MiniBooNE : Current Status

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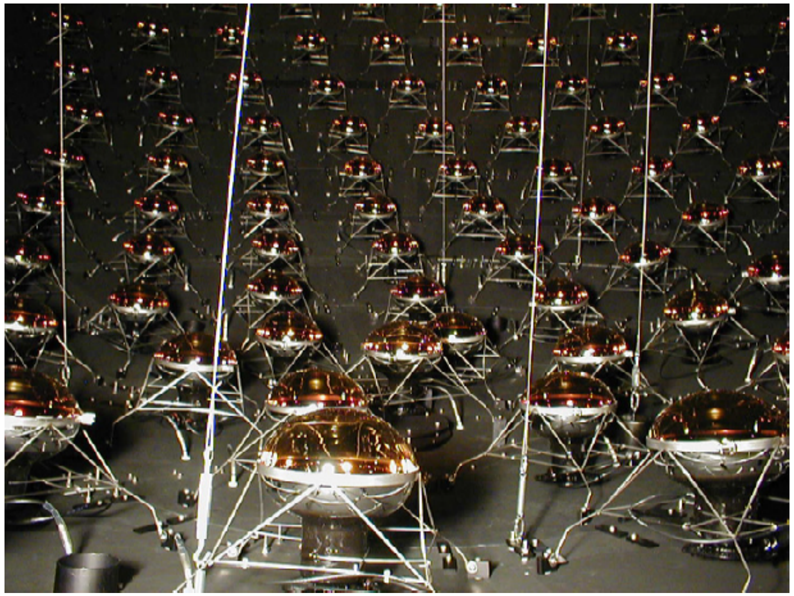
Outline

- Motivation
- MiniBooNE
  - ⇒ Beamline, Horn, Target, Tank
- Steps to Analysis
  - ⇒ Event Rate / Flux Predictions
  - ⇒ Calibrations
  - ⇒ PID
- MiniBooNE Physics
  - ⇒ ν_μ CCQE
  - ⇒ $CC\pi^+$
  - ⇒ NC π^0
  - ⇒ NC Elastic

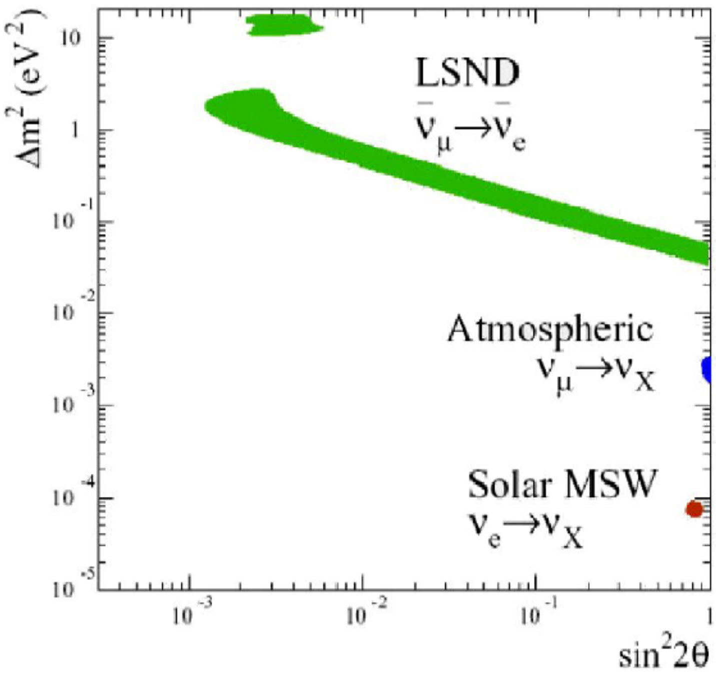
See Janet's talk Tuesday!

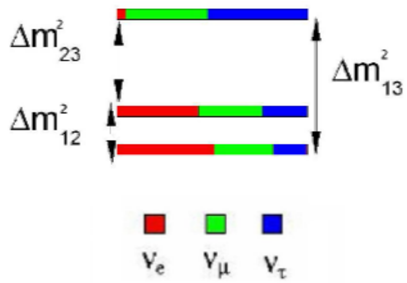


Current Oscillation Status

$P = \sin^2 2\theta \, \sin^2(1.27 \, \Delta m^2 \, L/E)$

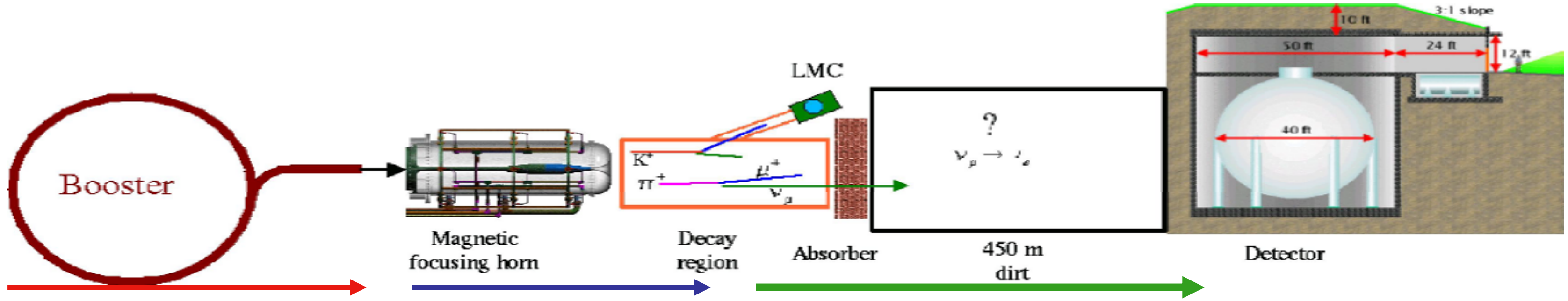
- Solar ν
  - $\Rightarrow$ Deficit of ν_e from $\odot$
  - $\Rightarrow$ $\Delta m^2 \sim 8\times10^{-5}$ eV^2
- Atmospheric ν
  - $\Rightarrow$ Zenith angle deficit of ν_μ
  - $\Rightarrow$ $\Delta m^2 \sim 2\times10^{-3}$ eV^2
- LSND Accelerator Result
  - $\Rightarrow$ Excess of anti-ν_e in anti-ν_μ beam
  - $\Rightarrow$ $\Delta m^2 \sim 0.1$ to 10 eV^2





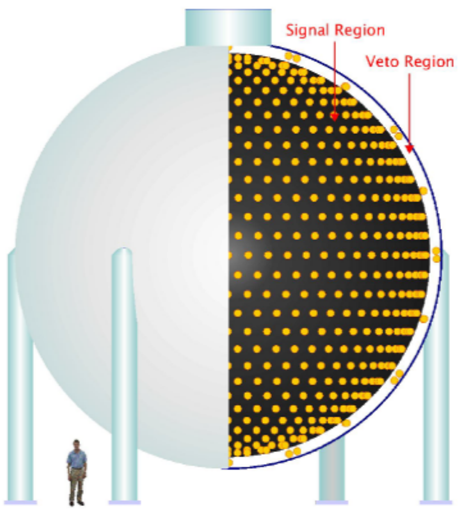
Need ~same L/E, different systematics

Beam, Horn, Target

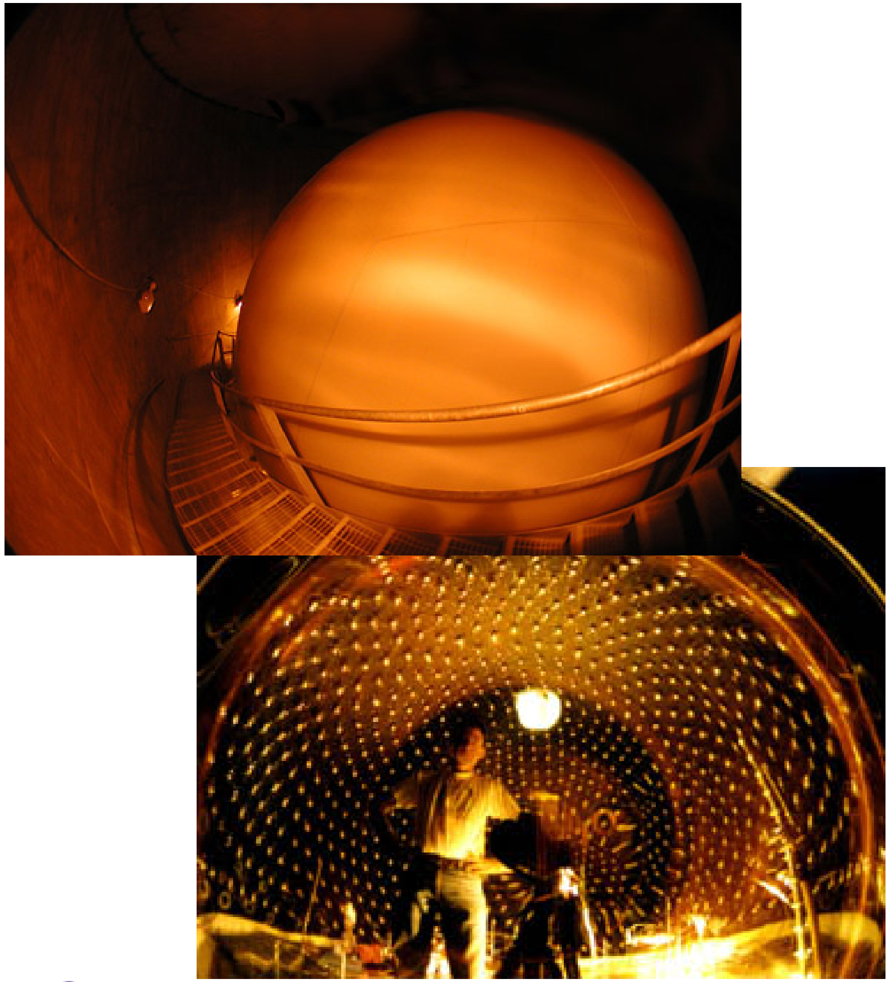


- 8 GeV proton beam
  - $\Rightarrow$ 1.6 μs pulse, 5 Hz rate from Booster
  - $\Rightarrow$ p + Be $\rightarrow$ mesons
- Mesons focused by magnetic horn
  - $\Rightarrow$ focusing increases ν flux by factor of 6
  - $\Rightarrow$ allow ν, anti-ν running
- Mesons $\rightarrow$ DIF ν
- E ~ 700 MeV, L ~ 541 m (L/E ~ 0.77 m/MeV)

MiniBooNE Detector



MiniBooNE Detector

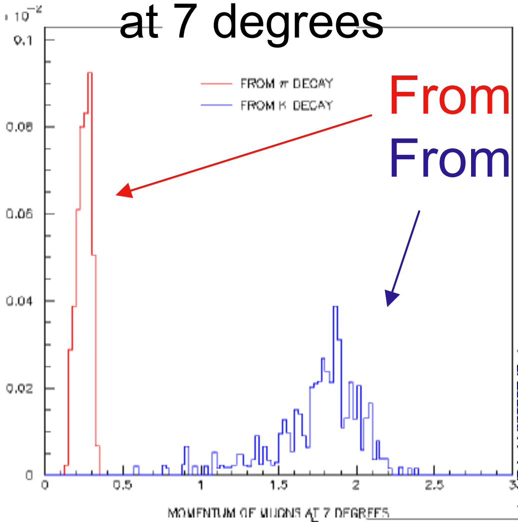


- 800 Ton, 12 m diameter sphere
- Non-scintillating mineral oil
- Two regions
  - ⇒ Inner light-tight region, 1280 pmts (10% coverage)
  - ⇒ Optically isolated outer veto-region, 240 pmts
- Signature
  - ⇒ Cerenkov and Scintillation
- MiniBooNE vs LSND
  - ⇒ Energy of beam : 8 GeV vs 800 MeV
  - ⇒ ν : DIF vs DAR
  - ⇒ Oil : non-scint, vs scint
  - ⇒ Backgrounds : mis-ID vs cosmics

Event Rate/Flux Predictions

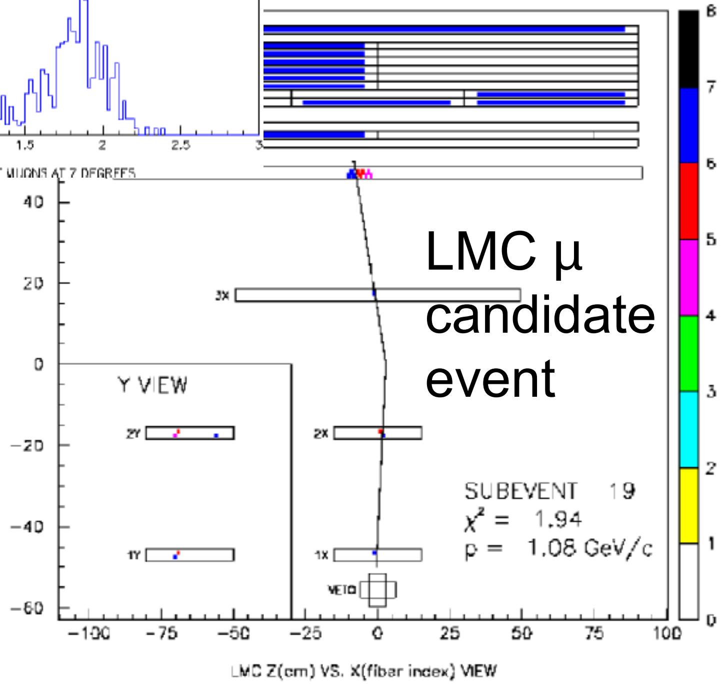
- ν_μ flux
  - ⇒ $\pi^+ \to \mu^+ \nu_\mu$
- Intrinsic ν_e flux
  - ⇒ From μ^+, K^+, K^0_L
  - ⇒ ~0.4% of ν_μ flux
  - ⇒ comparable to osc signal!
- E910
  - ⇒ π, K production @ 6, 12, 18 GeV w/thin Be target
- HARP
  - ⇒ π, K production @ 8 GeV w/ 5, 50, 100% λ thick Be target
- LMC spectrometer
  - ⇒ K decays produce wider angle μ than π decays
  - ⇒ scintillating fiber tracker

Momentum of μ at 7 degrees



From π decay
From K decay

LMC μ candidate event



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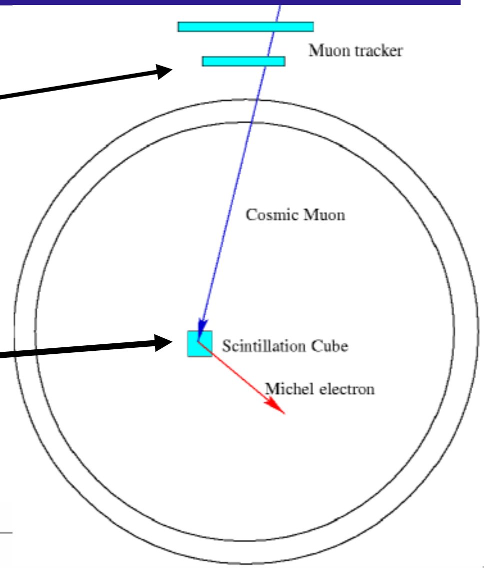
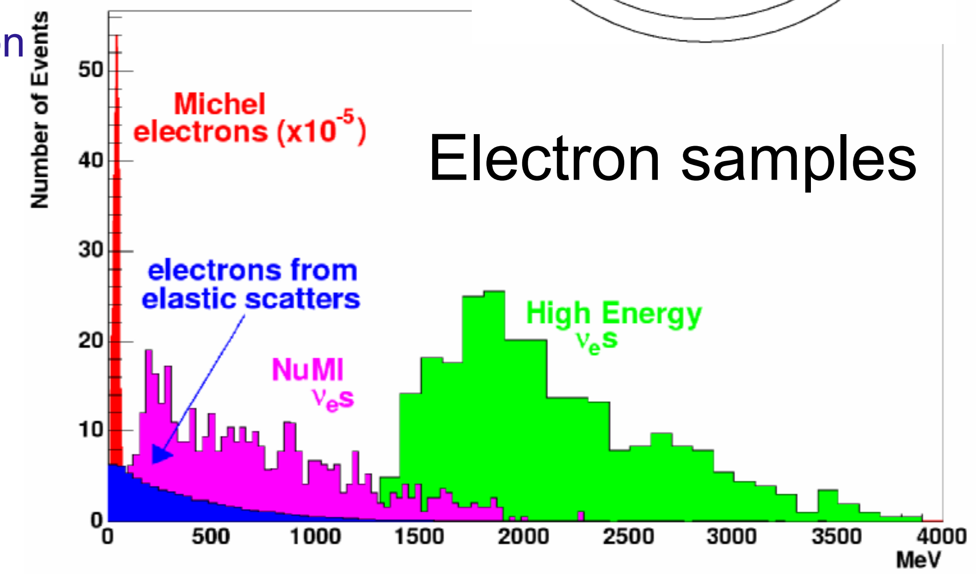
Calibrations

- Laser Flasks (4)
  - ⇒ Measure tube Q, timing response
  - ⇒ Change I = study PMT, oil
- Muon tracker
  - ⇒ Track dir + entry point = test track reconstruction in tank
- Cube System (7)
  - ⇒ Optically isolated scint. cubes
  - ⇒ + tracker = identify cosmic μ, michel ele of known position for E calibration
- Energy Calibrations
  - ⇒ Michel Electrons : fix detector E scale, 14.8% E reconstruction @ 50 MeV
  - ⇒ π^0 : mass peak, E scale and resolution at medium E

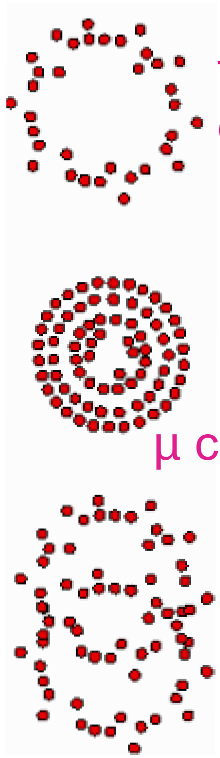




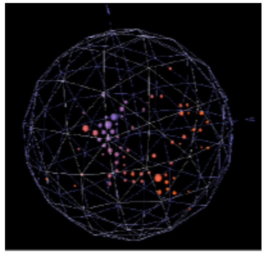
PID

- Identify events using hit topology
- Use a “boosted tree” algorithm to separate e, mu, pi, delta
  - ⇒ More stable than ANN in performance and sensitivity to MC optical model
- PID Vars
  - ⇒ Reconstructed physical observables
    - Track length, particle production angle relative to beam direction
  - ⇒ Auxiliary quantities
    - Timing, charge related : early/prompt/late hit fractions, charge likelihood
  - ⇒ Geometric quantities
    - Distance to wall

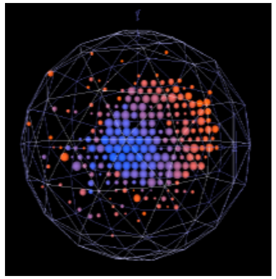
Nuc. Inst and Meth A, Vol 543/2-3



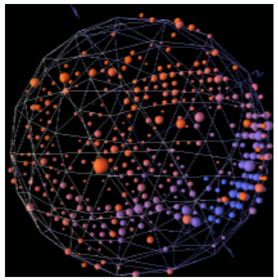
Michel e from μ decay



μ candidate

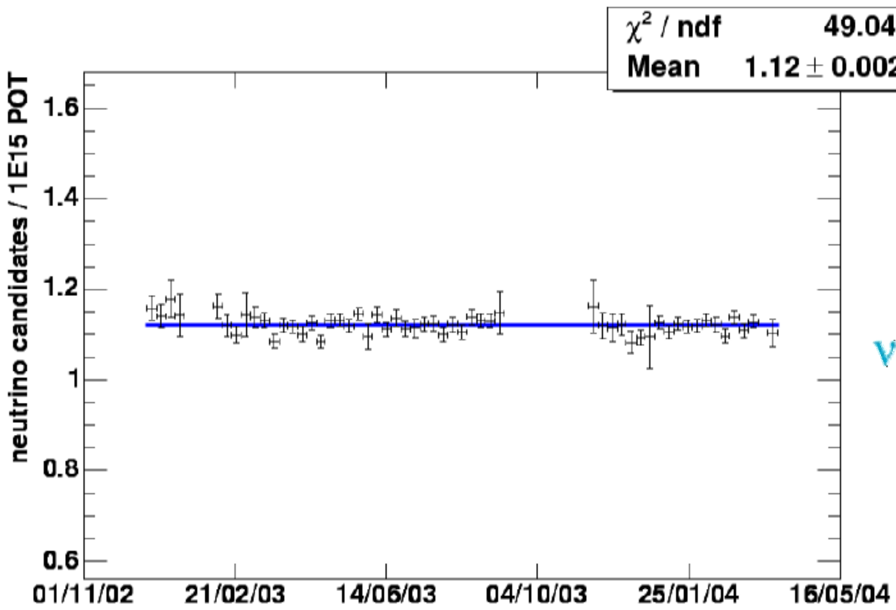


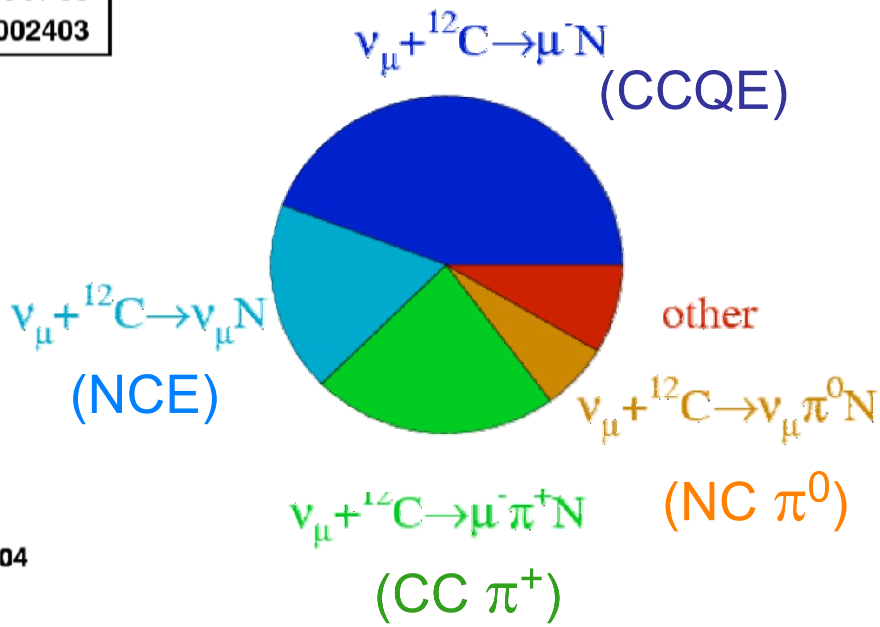
π^0 candidate



Physics Intro

- >570K neutrino events to date, > 1 million expected
- ~222K CCQE
- ~141K CC π^+
- ~90K NC Elastic
- ~39K NC π^0



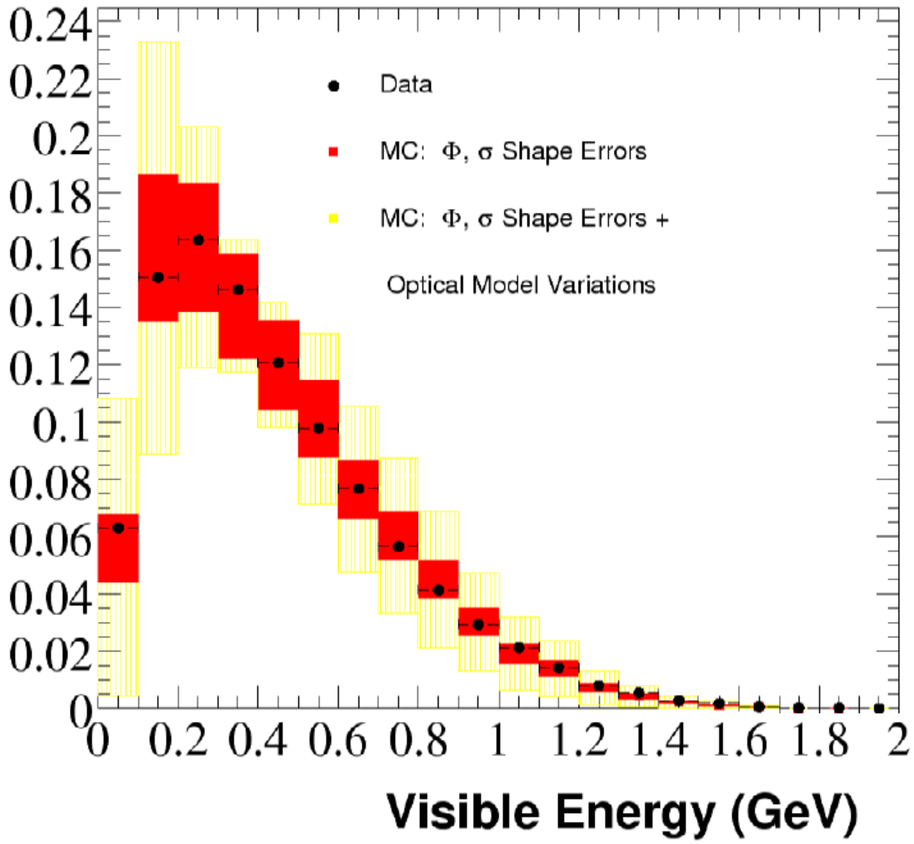


ν_μ CCQE Events

- Relevance
  - ⇒ Largest class of evts; use to validate flux, σ predictions
  - ⇒ Similar kin and cross section as ν_e signal in appearance
  - ⇒ Intrinsic ν_e bgd due to μ decay can be constrained
  - ⇒ Sensitive to ν_μ disappearance for $\Delta m^2 \sim 0.1 - 10\ eV^2$
- Event Selection
  - ⇒ Use Fisher discriminant to isolate events with μ-like Cerenkov ring in final state
  - ⇒ 80% purity, 55% efficiency
  - ⇒ Use of PID outputs provide 94% pure sample (in progress)
- Preliminary comparisons between measured distributions and MC expectations
  - ⇒ Ex: Q^2 (sensitive to nuclear effects such as Pauli blocking, nuclear shadowing)

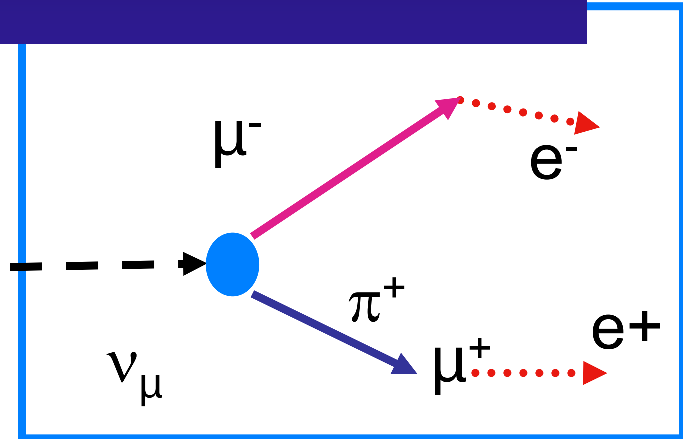
ν_μ CCQE Events

- Red error bands
  - ⇒ Flux errors
    - π^+ production, will be measured to 5% with HARP
  - ⇒ Cross section errors
    - CCQE from axial mass uncertainty, threshold effects, Pauli blocking
- Yellow variation bands
  - ⇒ Flux, Cross section, Optical Model variation
    - Optical model NOT 1 sigma, reflect current uncertainty on optical model parameters
- Data points
  - ⇒ ~ 50% of pot to date

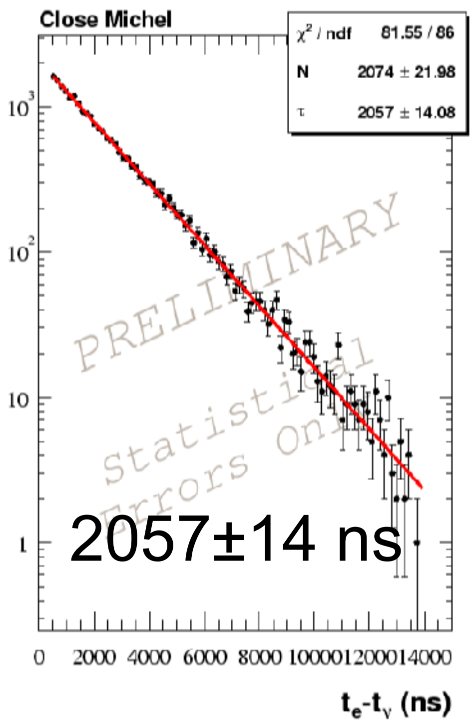


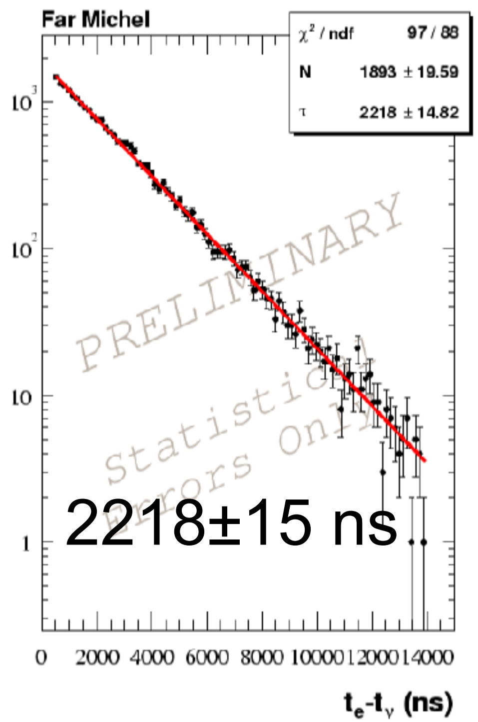
$CC\pi^+$ Events ..

- Relevance
  - ⇒ Primary background to CCQE evts/analysis
  - ⇒ All previous measurements at bubble chambers, 7000 total evts, all on light targets, few measurements at low E
  - ⇒ Use for sep osc measurement



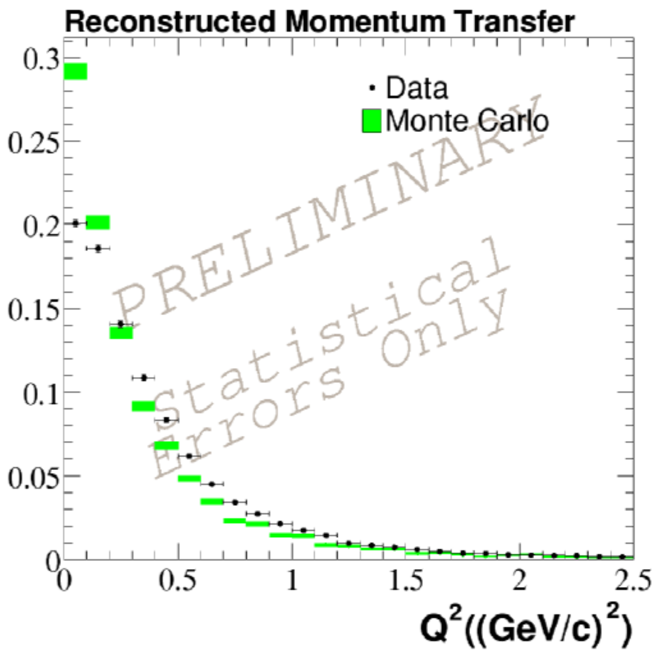
- Event Selection
  - At least 2 Michels,
  - parent neutrino event in beam
  - Separate into near and far Michels based on distance to muon track
  - ⇒ Close Michels from μ^-
    - μ^- capture on C
    - τ = 2026±1.5 ns
  - ⇒ Far michels from μ^+
    - τ = 2197±0.04 ns

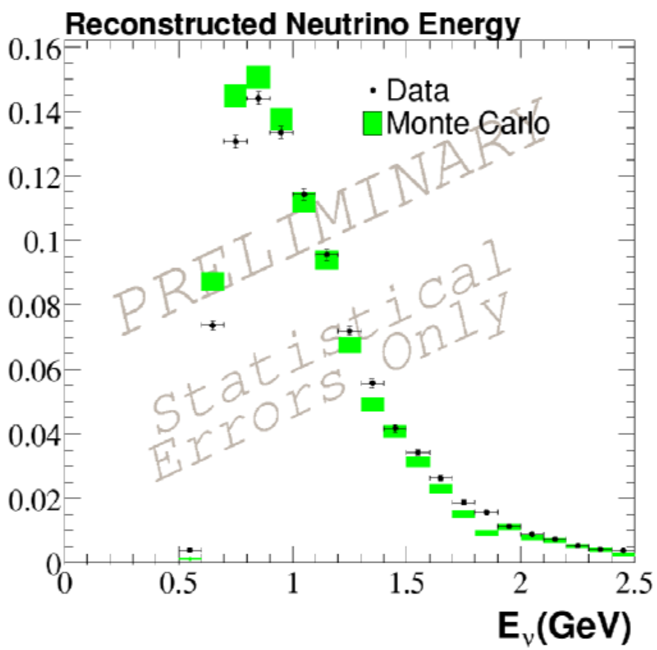


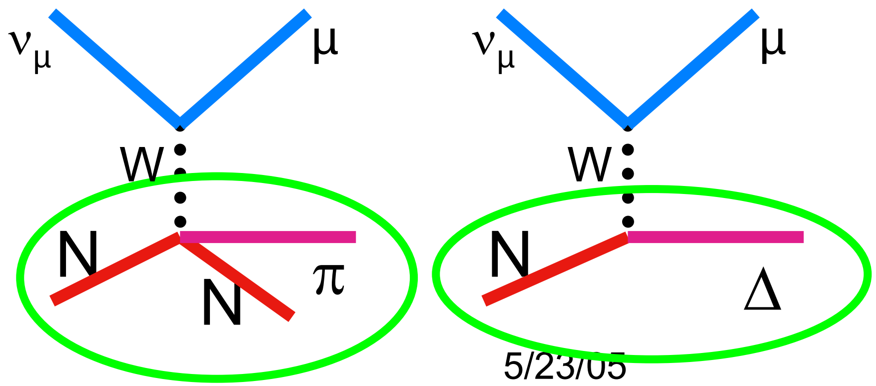


CCπ^+ Events

- Simple reconstruction (for now)
  - ⇒ Assume events are QE with Delta, instead of having recoil nucelon
  - ⇒ Don't use pion information in reconstruction

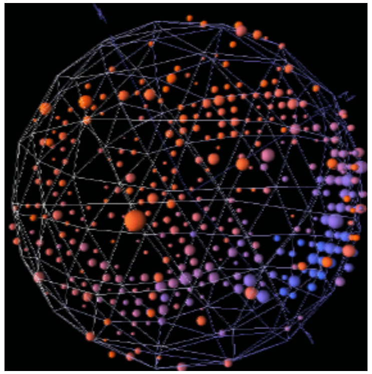






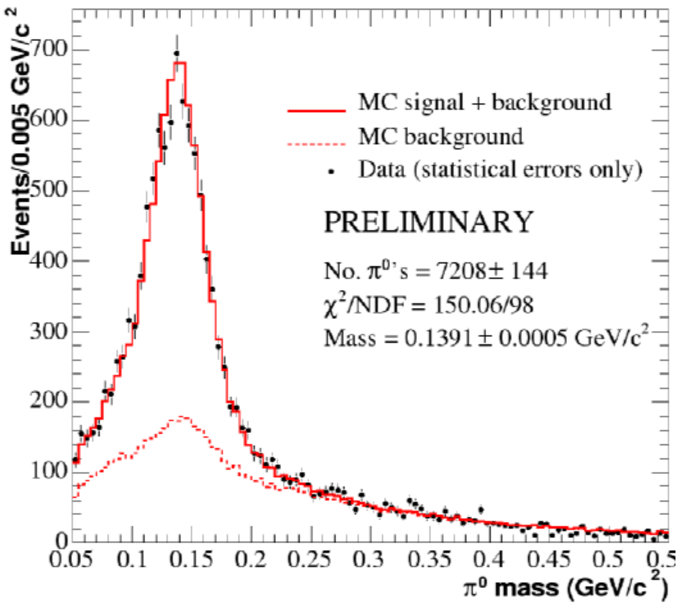
NC π^0

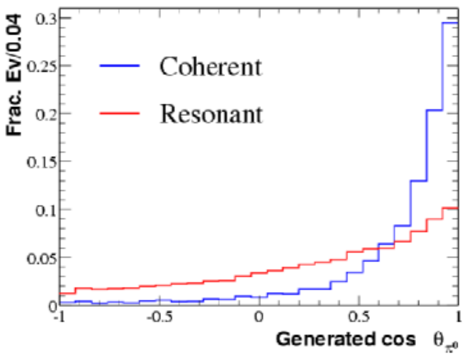
- Relevance
  - $\Rightarrow$ Background to ν_e appearance (dominant mis-ID)
  - $\Rightarrow$ σ : crucial for distinguishing ν_μ->ν_τ, ν_μ->ν_s in atm.
    - + angular distribution constrain mechanisms for production

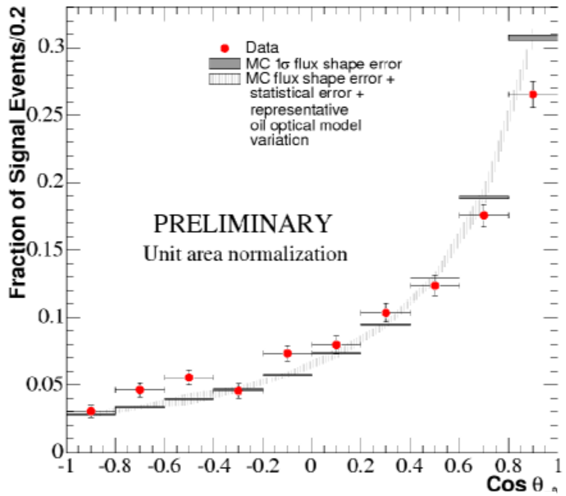


- Event Selection
  - $\Rightarrow$ No decay ele, 2 Cerenkov rings > 40 MeV each
  - $\Rightarrow$ signal yield extracted from fit with bgd MC : fit assuming 2 rings
  - $\Rightarrow$ Reconstruction : 55% sample purity with 42% efficiency
- Examine mass spectrum, kinematics
  - $\Rightarrow$ Bin data in kin. quantities : π^0 momentum, E asymmetry, angle of π^0 relative to beam, extract binned yields
  - $\Rightarrow$ Compare distributions to MC expectations

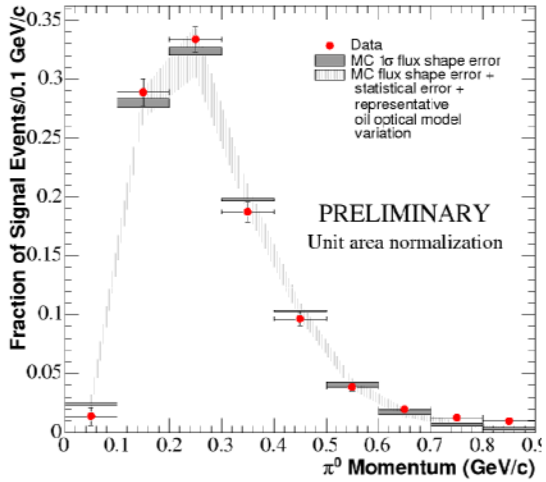
NC π^0







Errors are shape errors
Dark grey : flux errors
Light grey : optical model

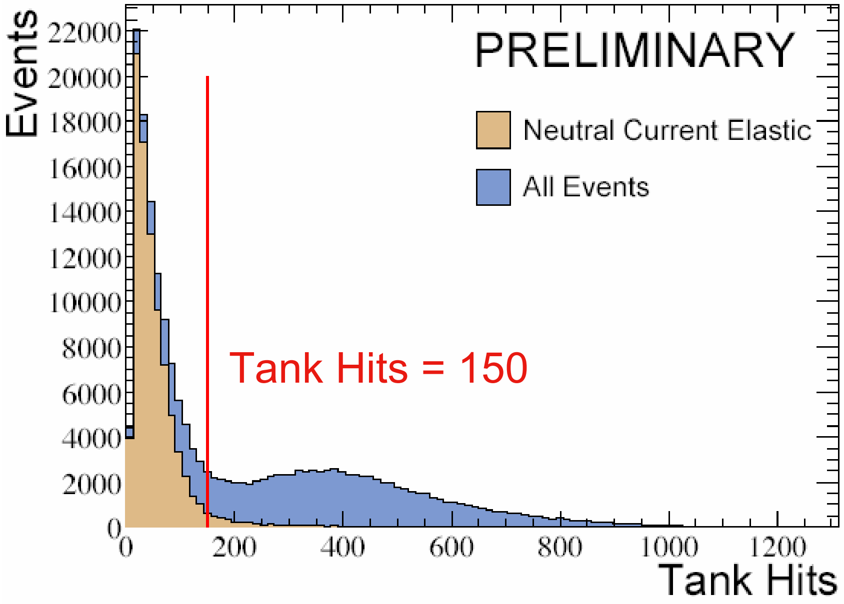


⇒ π^0 momentum = good data/mc agreement. Falloff at high p = due to flux falloff

⇒ Cos $\theta_{\pi 0}$ sensitive to production mechanism (coherent = forward, resonant = not so forward)

NC Elastic

- Study scint. properties of oil, low E response of detector
  - $\Rightarrow$ Reconstruct p energy from scint. light
- Measure σ (p+ν->p+ν)
  - $\Rightarrow$ Help understand scint. light for ν_e osc analysis
- σ(NCE) / σ (CCQE)
  - $\Rightarrow$ Measure Δs (component of proton spin carried by strange quarks)



Tank hits < 150, veto < 6, 1 sub-event : ε = 70%, purity = 80%

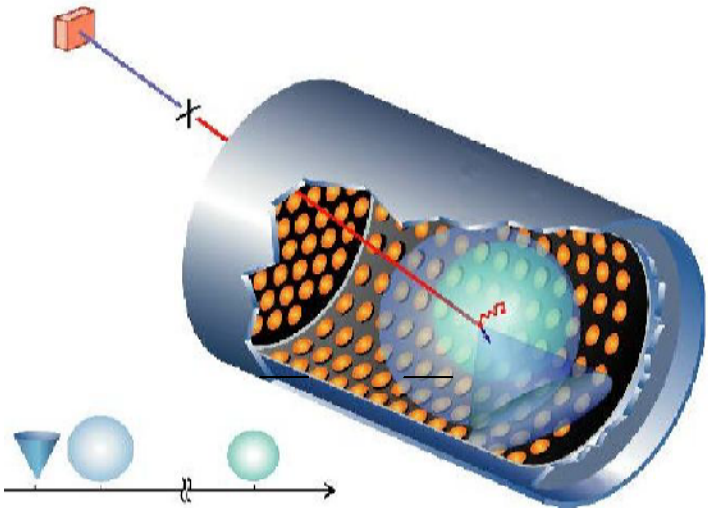
Conclusions

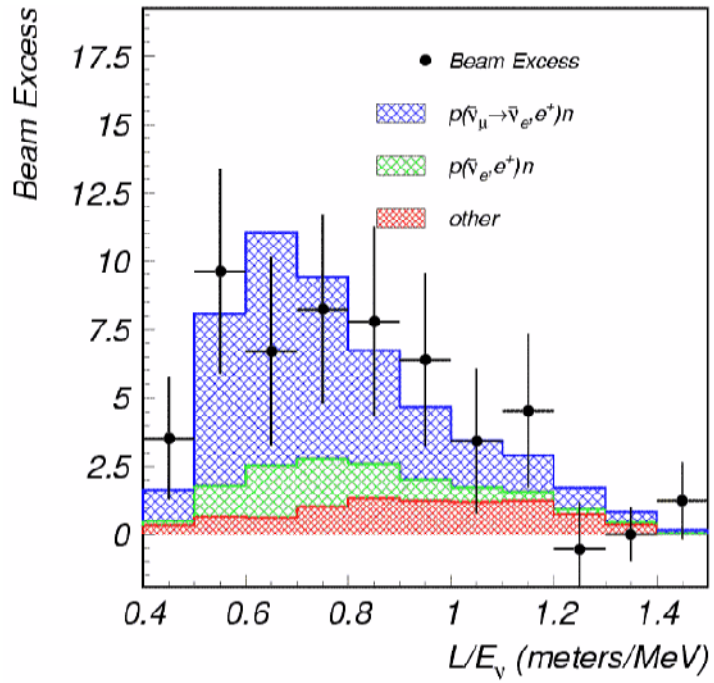
- ➔ Accumulated >50% of 10^{21} pot needed for 4-5 σ coverage of LSND
- ➔ Already have worlds largest ν dataset in 1 GeV range
- ➔ Reconstruction and analysis algos are working well :
  - ⇒ CCQE : compare with flux predictions, disappearance analysis
  - ⇒ CC π^+ : measure cross section, oscillation search
  - ⇒ NC π^0 : measure cross section, analyze coherent contribution
  - ⇒ NC Elastic : measure ratio of cross sections vs Q^2
- ➔ ν_e appearance analysis well under way; plan on opening box in late 2005/early 2006

Backup Slides

LSND

- 800 MeV proton beam -> water target
- 167 ton, liquid scintillator, 25% PMT coverage
- E ~ 20-53 MeV, L ~ 25 - 35 m (L/E ~ 1m/MeV)
- Measure $\nu_{\mu \rightarrow} \nu_e$ osc. from DAR
  - $\Rightarrow$ P = 2.64±0.67±0.45 x 10^{-3}, see 4 sigma excess





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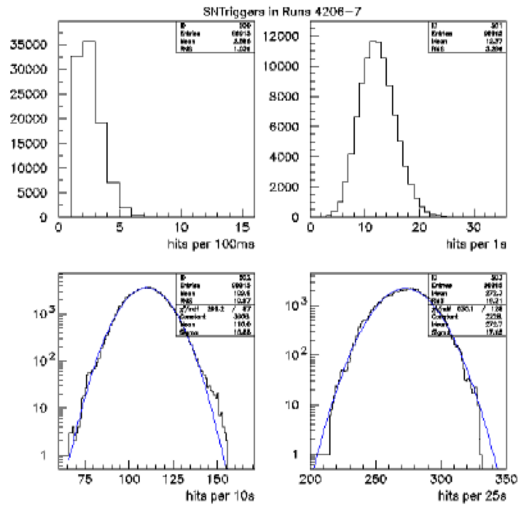
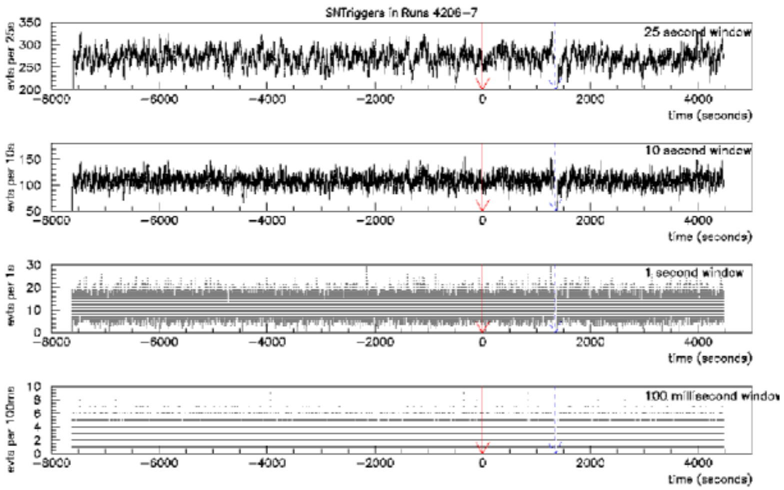
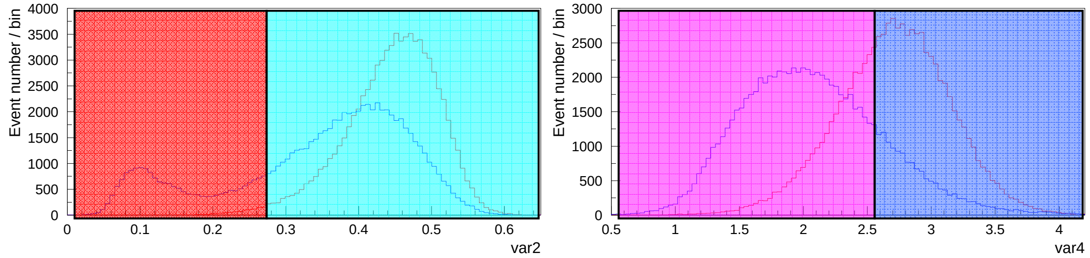
Exotic Searches

- Muon magnetic moment search
  - ⇒ Massive $\nu \rightarrow \nu_R$, expect non-zero muon mag moment
  - ⇒ Need full dataset
- Rare particle searches
  - ⇒ Take advantage of beam structure
  - ⇒ Proton dribble monitor (if p between buckets, no search!)
- Astrophysics
  - ⇒ Supernova searches
    - Gamma Ray bursts (GRB 030329)
  - ⇒ Solar flare emission searches
  - ⇒ Gamma Ray bursts



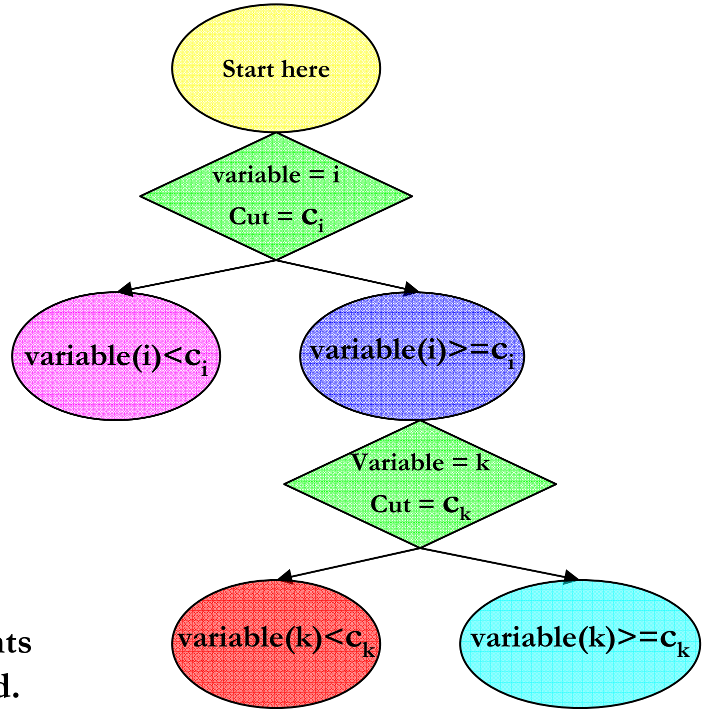




1. Boosting: how to split node ? – choose variable and cut

Define Gini Index = P (1 - P) and P $=\sum\omega^{S} / \sum\omega^{(S+B)}$ here, ω is event weight
For a given node, determine which variable and cut value maximizes:

$$\mathcal{G} = \text{GiniIndex}^{\text{Father}} - (\text{GiniIndex}^{\text{LeftSon}} + \text{GiniIndex}^{\text{RightSon}})$$

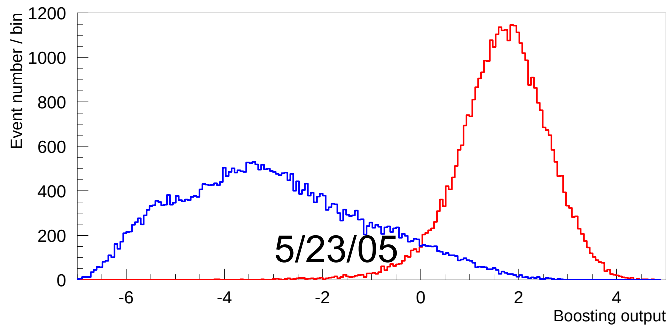


2. Boosting: how to generate tree? – choose node to split

Among the existing leaves, find the one which gives the biggest $\mathcal{G}$ and split it. Repeat this process to generate a tree of the chosen size.

3. Boosting: how to boost tree ? – choose algorithm to change event weight

Take ALL the events in a leaf as signal events if there are more signal events than background events in that leaf. Otherwise, take all the events as background events. Mark down those events which are misidentified. Reduce the weight of those correctly identified events while increase the weight of those misidentified evens. Then, generate the next tree.



4. Boosting: output value – sum over (polarity x tree weight) in all trees

See B. Roe et al. NIM A543 (2005) 577 and references therein